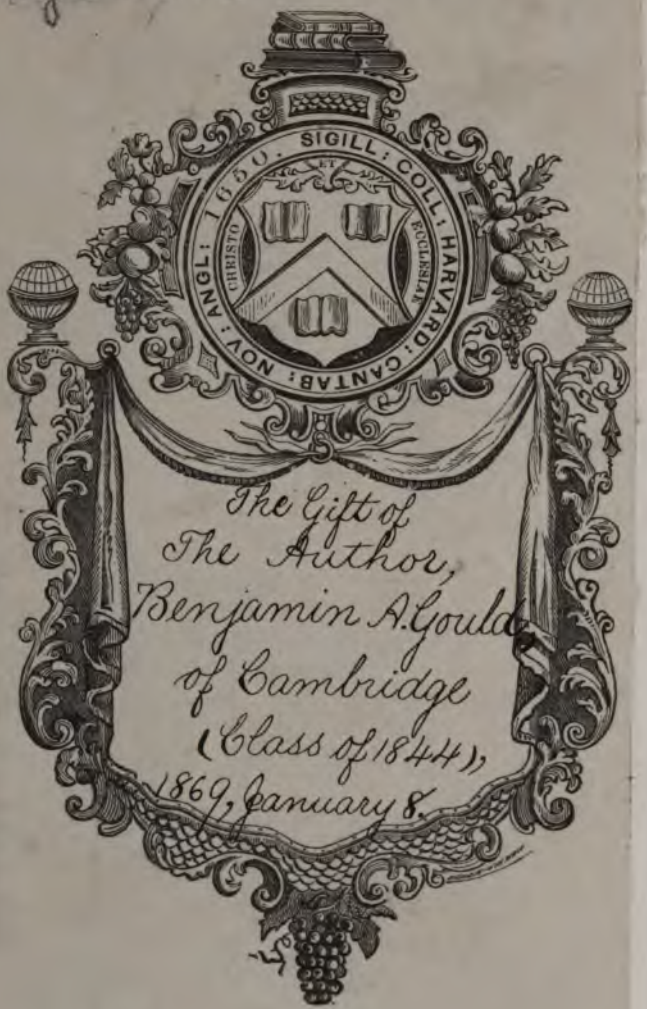

AN

ADDRESS

IN COMMEMORATION OF

ALEXANDER DALLAS BACHE,

DELIVERED

AUGUST 6, 1868,

BEFORE THE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,

BY

BENJAMIN APTHORP GOULD,

President of the Association.

SALEM, MASS.
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BY

BENJAMIN APTHORP GOULD.

GENTLEMEN OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:—

IT is no common event which you have called upon me to commemorate. Death, who comes with an impartial tread into the hovels of the poor and the castles of monarchs, is a visitor too well known to us all. Yet, sometimes he assumes a new aspect. When, three years ago, at the very moment of the hard won and stern rejoicing of the Republic, we saw her first citizen struck down in the midst of the people who honored him, the destroyer gained almost a new power in our imaginations. So is it with us now. He, who by common consent, unquestioning and unchallenged, stood forth preëminent as our leader in science, our first counsellor where her welfare was at stake, unflinching in the maintenance of her interests, wise in the guidance of her affairs,—he has gone from among us.

Adequately to portray the character, abilities and influence of such a man would be an undertaking from which the ablest tongue or pen might shrink. It is not for the labor it implies, for labor is fitly bestowed in recording a life at once so great and so inspiring; not from the natural timidity, which even the most competent might well feel, in presuming to pronounce any judgement upon so rare a virtue, ability and patriotism; nor is it even that our point of view is palpably too near, to permit the just portrayal of this lofty character with all the truthfulness of outline for which a comprehensive survey of the whole in its

many relations is imperative; or to give its fair proportions, undistorted by the mists which encompass our vision, and untinged by the hues with which affection adorns his image. Beside all these, there is yet another reason for distrust. His influence extended through so large a sphere that it is difficult for us fully to comprehend it now. The more we examine the tokens of its action, the more do we become impressed with its extraordinary range. I know of no department of physical or natural science which has not been stimulated or fostered through his means. The legislative and executive departments of the nation knew his power through many years, and relied upon it in matters far beyond the range of his ordinary pursuits. Both the army and navy felt, and have often acknowledged their obligations to him. The progress of education, the development of scientific research, the extent of scientific discovery, the growth of the arts, and the spread of commerce, have all been greater in America because he has lived.

Such a man was our beloved and honored BACHE. To hesitate, when summoned to put into words our common tribute, were unworthy of his friend or of his pupil. You will all feel the inadequacy of the offering, and the futility of attempting to compress into the utterance of an hour or two such records and such results. Many of you have already brought him a better tribute,—that of years of fruitful labor, prompted and encouraged by himself, or of a change in the aims and pursuits of a lifetime, induced by his wise and kindly counsel.

ALEXANDER DALLAS BACHE was born in Philadelphia on the 19th day of July, 1806. If intellectual and moral eminence might be inferred from an honorable lineage, which, unhappily, is not always the case, it certainly would have been anticipated for him. His father was the son of Richard Bache and Sarah Franklin; the former, President of the Republican Society of Philadelphia at the outbreak of the American Revolution, and Postmaster General of the United States from 1776 to 1782; the latter, the only child of Benjamin Franklin and his wife Deborah (Read), and herself eminent as one of the heroines of the war of independence. The noble women who, during our recent struggle for the maintenance of the nationality the achieved, gave their time and energies to the support of the

countrymen facing the edge of battle, and who have aided in making the name of our own Sanitary Commission immortal, were but the unconscious imitators of that smaller but equally devoted band who, during our first struggle for national existence, similarly labored in mitigating the sufferings of our soldiers. Like them, Mrs. Bache ministered to the sick and wounded in army hospitals; and under her superintendence more than 2200 women were at one time employed in making garments for the barefooted and half-clad men, who, against almost unparalleled obstacles, were achieving the independence of a continent and a new vantage-ground for the oppressed of all nations. The maternal grandfather of our departed colleague, for whom he received his name, was Alexander James Dallas, Secretary of the Treasury of the United States from Oct. 1814 to Nov. 1816, who, in the second war of our Republic, redeemed its finances from confusion, and, in the short space of two years, restored them to a condition of order and stability. Under his administration also, the Coast Survey of the United States was established, and Mr. Hassler appointed to its superintendence. The late Commodore Dallas, and Mr. George M. Dallas, Vice President of the United States, were his sons.

A peculiarly large number of Mr. Bache's family, both on the paternal and maternal side, were engaged in the government service, civil or military, and young Bache was destined by his father for the army, which offered also to the boy an attractive career. Accordingly, at the age of fifteen, he entered the Military Academy at West Point, where he graduated, July 1, 1825, the first scholar in a class so far above the usual grade of excellence that four of its members were assigned to the Corps of Engineers, although for more than one or two in each class to attain this distinction was a rare occurrence. Among his classmates at West Point were General Robert Anderson, of Fort Sumter, and Major-General C. F. Smith, who served his native land so faithfully and effectively during the recent rebellion.

It is recorded of Bache that, during the whole term of his course at the Military Academy, he never incurred a single mark of demerit. And this is all the more to his credit, in that

he was no demure and prematurely sedate youth, but possessed, in an eminent degree, that love of frolic and of jest which formed a prominent trait of his character in riper years. Nor was the high position which he acquired in the confidence and respect of his instructors attained at the expense, in any degree, of the affection of his fellow pupils. The bonds of friendship formed within the precincts of the Military Academy seem to have been of remarkable strength, and were most tenderly guarded by him throughout his subsequent life.

The final examination of the cadets, just before the close of their academic course, was attended then, as now, by prominent officers of the military service. In the year now referred to, the Secretary of War himself was present, and the tokens of scholarly and military excellence given by the first pupil of the class were such as to elicit the most uncommon marks of approval. The Secretary himself, with a sympathetic appreciation which does him the highest honor, was prompted to the unusual step of addressing a letter to Bache's mother. This letter, one of that mother's most cherished mementoes, I am permitted to read to you.

WEST POINT, June 10th, 1825.

My Dear Madam:—Upon any other occasion than the subject of the present letter, I should be obliged to admit that our very small acquaintance would rebuke me for addressing you. But, being a father, and knowing how exquisite is the pleasure arising from the well-doing of children, I am quite sure, from your amiable disposition, that you will forgive me, when you learn that my only purpose in writing is to state, as I do most sincerely, how greatly I was gratified at the evidences given by your son in his examination, of the excellence of his attainments. He ought to be, as I am sure he will be, a source of the greatest consolation. I know not whether it has been your lot to have your cup of life drugged in any degree with calamity. The draught must have been severe indeed if it is not sweetened by the blessing of your excellent son. I knew and loved your father—his great paternal ancestor I knew only by his works. I thought, or permitted myself to believe, that I saw the excellences of both branches about to be united in your son. I offer you my sincere congratulations.

JAMES BARBOUR.

MRS. SOPHIA BACHE.

That mother's cup of life was indeed bitterly drugged with calamity; but the supporting arm of her son, the rich honors

which she happily lived to see accorded him in no stinted measure, and the abundant benefits to the commonwealth and to the nation, which followed his accession to each successive place of influence or authority, did most effectively sweeten it, and cause it to run over with gladness.

During the first year after graduating, he remained at West Point, as assistant to Professor Mahan in the department of Engineering, and, in the summer of 1826, was detailed as assistant to Colonel Totten, then in charge of the construction of Fort Adams, at Newport. Here commenced a close friendship between these two eminent men, which increased with their increasing years, and was severed only by death. And when, long years afterwards, their duties brought them once again to the same place of residence, and permitted a resumption of their intimate communion, the joint influence of General Totten, as Chief of the Engineer Corps, and of Professor Bache, as Superintendent of the Coast Survey, quietly but steadily wrought a wondrous change in the welfare of scientific interests, and in the position of scientific men at Washington. In their intimate domestic intercourse they not only occupied the relation, but assumed the titles of kindred; and to their mutual support in times of peril to the great intellectual interest which they defended, American science will be forever indebted.

Nor was General Totten the most important or the nearest friend whom Bache won for life during his sojourn of two years at Newport. It was his privilege there also to enlist the affection and secure the hand of an admirable woman, who, for nearly forty years, accompanied him in all his many wanderings; by her sound judgement, unsurpassed devotion, and intellectual ability, multiplying his opportunities of usefulness as well as his happiness, and rendering it possible for him to accomplish, for his own honor and for the welfare of his country, what no man probably could have accomplished without some such assistance.

On the 16th of September, 1828, only three years after graduating from West Point, and only two years after the commencement of his professional duties at Fort Adams, Mr. Bache was elected Professor of Natural Philosophy and Chemistry in the University of Pennsylvania, at Philadelphia. He was at

this time but twenty-two years old, yet the repute of his career at West Point had been already a source of pride to his native city, and sundry communications, which he had found time in Newport to contribute to the *Mathematical Journal*, had borne witness to his mental activity and ability. Mr. Bache obtained a six months' leave of absence, was married as soon as it was received, and, on the 11th of October, about three weeks after his election, arrived in Philadelphia to assume the duties of his professorship. These duties proving acceptable to himself and to the college authorities, he definitely resigned his position in the army at the expiration of his leave of absence.

Here commences his scientific career, interrupted sometimes by the pressure of other duties, but never discontinued, no matter what his avocations, so long as God granted him and us a continuance of his mental powers.

For seven years Professor Bache retained his position in the University, beloved by his pupils, esteemed by his colleagues, respected by the whole community. During these years he was an active member of the Franklin Institute and of the Philosophical Society, and their transactions contain some twenty-five contributions from him within this period, all of them recording the results of original scientific research.

Among these papers some deserve especial mention.

The earliest which I find recorded is an article "On the Specific Heat of the Atoms of Bodies," published in February, 1829. In this firstling he maintained that the best and latest determinations of the atomic weights and specific heats of elements failed to support the doctrine that the specific heat of the atoms is the same for all bodies. The topic was a large one for discussion by a young man of twenty-two, but he certainly made his point good; and if the theory which he then opposed has found acceptance in subsequent years, it has only been because the data upon which it rests have been modified by more accurate determination.

This paper was followed, a year later, by his first experimental research, which was upon the inflammation of phosphorus in a vacuum, or rather, in a highly rarified medium. This appeared in the *American Journal of Science*, bearing date May, 1830, and was the beginning of a more extended line of investigation,

subsequently followed up. A stage was reached, at last, where it became requisite to learn the order of thermal conducting power for various powders, since the research depended on the degree to which that small amount of heat could be retained, which was generated by means of what little oxygen remained for contact with the phosphorus. In the air many powders were capable of thus producing inflammation; and exhaustion of the air operated simply by removing a conveyer of heat. These conducting powers were not determined, and the research remained unpublished.

The influence of the Franklin Institute, in giving to Bache's first researches an especially practical character, is very noticeable at this period. General Mechanics received a large share of his attention. An article which he printed in April, 1831, proposes a safety-apparatus for steamboats, composed of a combination of the French plan of plates of fusible metal, with the ordinary safety-valve, so that on the melting of the plate the supply of steam might not be totally lost, thus obviating the main objection to the employment of fusible metal. A year later, he proposed an alarm to be applied to the interior flues of steam boilers. In this, the ordinary difficulties attending the use of fusible metal for such purposes are obviated, by inclosing it in a tube, and imbedding in it the lower end of a rod, to the upper end of which is applied some retractive force. The fusion of the metal releases the rod, causing a bell to ring, or a whistle to sound; after which the rod may be restored to its place, and the metal allowed again to solidify around it. Thus the metal is not exposed to the contact or pressure of the steam, but only to its heating agency. Experiments tried with this apparatus a year or two later, by the Committee of the Franklin Institute on Explosions of Steam Boilers, led to a very favorable report, accompanied by the suggestion that it is equally applicable to boilers without interior flues, and might be employed as a manageable and useful check in ordinary cases upon the safety-valve.

In the beginning of the year 1832, Mr. Saxton, who was then in London, wrote to friends in Philadelphia an early account of Faraday's discovery of magneto-electricity, and of his own repetition of the experiments, as well as those of Nobili made

soon afterwards. Apparatus was immediately constructed for repeating the experiment, both in the English and Italian form, and careful observations were published by Professor Bache in the Memoirs of the Franklin Institute for July. His inferences were most philosophically and accurately drawn, and entirely accord with the laws now so well known. What a field has been traversed in the progress of our physical knowledge since that not very distant day! The production of a spark by magnetic agency was a vast step toward making possible the quantitative demonstration of the Correlation of Physical Forces. But Saxton, in writing, carefully says, "a spark resembling the electric spark;" and Bache's first inquiries were directed to solving the great question whether it were indeed electrical in its nature. A quarter-century later, and these sparks, "resembling the electric spark," were flashing messages of peace and good will to men between the home of Faraday and the home of Bache.

I pass over his translations of important recent physical and chemical memoirs, which did good in their day by bringing the newer results of science home to our doors, at a time when familiarity with modern languages was comparatively a rare accomplishment, and so also his experiments on the Navigation of Canals by Steam; but must comment, for an instant, on the interesting and valuable results of his experiments on the correctness of measurement of rainfalls made by the ordinary gauges. These observations were made in 1833, although not published until five years later, when he communicated them to the British Association at its meeting in Newcastle, which he attended. These experiments were very labored, and led to interesting deductions. He placed rain-gauges at each corner of Beck's shot tower, in Philadelphia, at a height of 162 feet from the ground. The locality was favorable, since Philadelphia is situated upon an extensive plain, where neither the falling rain nor the wind encountered purely local influences. The observations were made at first at three different heights, the original motive of the investigation having been, to determine the extent to which the amount of rain collected is affected by the height of the station. It soon became manifest that the effect of eddy-winds was greater than that of the difference of

elevation; and Professor Bache himself became convinced that the variation in quantity of rain collected at different heights was chiefly due to this previously unsuspected source of error. The quantities of rain collected at the different angles of the tower varied very greatly; and, in one extreme case, during a westerly wind, the quantity in the gauge at the south-east angle was $2\frac{1}{3}$ times as great as that in the north-west gauge. In general, the leeward gauge received more than the windward one. And since the heavier rains generally fall in connection with certain particular directions of the wind, it is clear that averages derived from observations of these rains are liable to constant errors, in the determination of the quantity of rain falling at a given height from the ground. Regarding the supposed variation in quantity as dependent upon variation in height, the results were far less marked; and, although the temperature of the rain-drops was often found higher than that of the air through which they were falling, he states that he never saw a case in which the gauges at the top of the tower showed more rain than those below. The extensive details of this research have not been printed. It was far from Bache's usage to send his papers abroad for publication, but these results were, with entire propriety, communicated to the eminent foreign scientific body whose sessions he was attending, a welcome and honored guest. Speaking of them in later years, he says: "The experiments have never been published *in extenso*, because I thought the cream of them had been taken off, and there was no use for the skim-milk!"

But the subject which, not only at this period but throughout his life, seemed to possess for him the greatest attraction was Terrestrial Magnetism, then made especially prominent as a field for physical investigation, through the experimental and theoretical discoveries of Gauss and Weber. As early as the year 1830, he had equipped a little magnetic observatory in the garden attached to his house, in which regular observations were made during a period of four or five years. In his journeys he carried with him portable instruments with which he determined the magnetic constants of the points visited. What he accomplished in later years for this favorite branch of science, the world knows; and it is certainly not too much

to say that, of what we know to-day of the distribution, intensity, and periodic and secular changes of terrestrial magnetism, we are indebted quite as much to Bache as to any other one man.

His first memoir on the subject was presented to the American Philosophical Society in November, 1832, and contains the results of hourly observations of the declinations, in which he was assisted by Professor Frazer. These observations were made with a very long needle, provided with a graduated arc at each end. Beside some small notices of the observed influence of Auroras upon the needle, a phenomenon regarding which facts were then wanting, he published, in the Transactions of the Philosophical Society, in connection with Professor Courtenay (at that time his colleague in the University of Pennsylvania), two very elaborate memoirs on the Dip and Horizontal Intensity of Terrestrial Magnetism at several places in the United States. The care and thoroughness with which these observations were arranged, and the reductions effected, could with difficulty be surpassed.

The illusive promises of brilliant results, so familiar to all students of the physical sciences, and which present such temptations to premature inferences, were not wanting in these magnetic investigations; but Bache, though a young man, was truly a philosopher, — as cautious in his deductions as he was keen in following up the track of an unusual phenomenon or the varied suggestions to which renewed experiment might afford a clue. These earlier observations exhibited an apparent connection between the weather and the amount of variation of the needle. Even the approach of a summer shower seemed to be announced by changes in the magnet. On the morning of the great meteoric display in 1833, Mr. Bache thought he had detected an unusual disturbance, — the needle, which was generally kept in the house, having been carried out to the observatory for greater convenience. But the same transfer, on subsequent mornings, produced the same effect, an effect afterwards referred to changes of temperature; and instruments within doors gave, through several seasons, different results from those observed out of the dwelling-house. Whether the changes of temperature occasioned an alteration in the mag-

netic axis of the needle, or to what other agency the result was attributable, remained undecided.

During the solar eclipse of 1834, before he had received the Gaussian apparatus, he carried out a careful series of observations to ascertain whether the magnetic forces were disturbed during the eclipse. For these observations he employed the long declination-needle already described, a horizontal bar vibrating in a rarefied medium, and a dipping-needle poised on a knife-edge. Writing of it nine years later, he says: "I had nearly cried 'Eureka' once, but had occasion afterwards to doubt." And again, in a tone almost of sadness, he adds: "The ordinary labors in magnetism are like those in astronomy; they yield no point of discovery, but go to the general accumulation of facts." To what extent he aided in such accumulation in later years, you know.

The observations of magnets during auroral displays promised, at the time, important results; and Faraday encouraged him to proceed in the same course. The formation of an auroral arch appeared to bring the declination-needle to a "point"; but the difficulties arising from the conflict of the testimony of different instruments were found very serious. To obviate these, he resorted to the mode of observation already alluded to, in which the needle was suspended in an atmosphere rarefied to the pressure of from three to three and one-half inches of mercury, a method described in the memoir cited, and which proved of importance for the light bars of Hansteen and others, before Gauss had shown the importance of heavy bars, and thus brought about their general use. Of this same memoir he makes a remark, in the letter to Professor Henry, from which I have already quoted, which may touch a sympathetic chord in the hearts of some of the seniors before me, who recall the intellectual position of the American investigator at epochs by no means so remote as this, of thirty-two years ago.

"This memoir," he says, "has been voted prolix. The reason for my making it in such detail was a sneering remark, that American observations were not given with the necessary detail to enable observers in Europe to judge of their value. Perhaps I erred in being so circumstantial. The neglect with which my friend, Major Sabine, treated these observations, on the plea that I had not combined the dip with them, and that they were over too limited an extent of coun-

try, hurt me much; and, in a controversy before the British Association, I charged upon him without drawing bridle, and with a *temporary* effect. The dip observations I was not satisfied with, at the time, having exaggerated ideas of the accuracy attainable in such things. When I saw other instruments and observations, I found that I had been unnecessarily fastidious."

Early in 1833, he published an edition of Sir David Brewster's Treatise on Optics, with Notes and an extended Appendix, giving the mathematical investigation of subjects concerning which the author had only given the results, in popular form.

In May, 1833, a bill having been introduced into the Legislature of Pennsylvania establishing and regulating the standard of Weights and Measures, then not fixed by the Federal government, the House of Representatives referred the bill to the Franklin Institute for their opinion. The Institute referred the matter to a special committee of nineteen, of which Mr. Bache was chairman. Their report was prepared by him, as well as a special analysis of the various reports previously made on Weights and Measures in the United States.

This report is worthy of especial note, since it doubtless contributed to hasten that desirable consummation, the establishment, by Congress, of a uniform standard of Weights and Measures, for which the power had been expressly delegated by the constitution. It took the strongest ground in favor of such Congressional action.

"So impressed are the committee with this view," says the report, "that they would express it as their decided opinion that the most imperfect system of Weights and Measures which has ever been framed, would, if applied in all the States of our Union, be preferable to the most perfect system which should be adopted by any one commonwealth singly. . . . Indeed, in most of the laws of more recent origin adopted by the several States, there is a distinct provision that when Congress shall furnish a system of Weights and Measures for the United States, the temporary State standards shall be made to conform to the national standard. The exceeding importance of uniformity is thus distinctly set forth from quarters of the highest authority in the different parts of our extended republic."

The report, which was signed by all the members of the committee, and unanimously adopted by the Board of Managers of the Institute, concluded by recommending that in-

dependent action on the part of the State be suspended for a season, but that the attention of Congress be especially called to the importance of fixing the standard of Weights and Measures.

Before long, Congress had taken the much needed action, and established uniform national standards, probably the best attainable without the introduction of new names and ideas; and before the expiration of a single decade from the date of this report, Mr. Bache himself occupied the position of Superintendent of Weights and Measures for the United States.

Like the great body of scientific investigators throughout the world, he felt the convenience and many advantages of the metric system, and fervently looked forward to the time when that uniformity, for which the individual States of America and of continental Europe were then earnestly striving, should find its application on a grander scale, and when all civilized nations, scorning the prejudices which rivers, oceans or mountains might hem in, should join in one measure, one weight, and one coin; deeming this apparently far off, yet not impossible, attainment to be not merely an efficient source of immediate benefit, but also a great step toward hastening on that happy era, sung by poets and foretold by prophets,—

> "When the war-drum throbs no longer, and the battle-flags are furled
> In the parliament of man, the Federation of the world."

The only hinderance to his immediate advocacy of the metric system arose from a fear that the nation was not yet ripe for it, that new names would alarm the illiterate, and that premature efforts for its introduction might defeat their own end. Still he retained the meter as the fundamental unit for all the measurements of the Coast Survey; and in all discussion and official action, whether in the United States Office of Weights and Measures, in his many relations to the Mint, or as Chairman of the Committees upon Weights and Measures in this Association and in the National Academy, his policy always had reference to that desirable epoch, which must surely come, when the metric system shall be thoroughly introduced into the United States. How would his heart have swelled with joy could he have foreseen that, even now, while I speak to you, this has been established as the standard of Weights and Meas-

ures for more than half, and legally authorized for two-thirds of the population of continental Europe; adopted by one-half of that of South America; that the United States have not only put it on the same legal footing as the old systems, but have introduced it into their domestic and foreign postal arrangements, and are issuing coins of metric dimensions and weight, for the purpose of disseminating among our people an acquaintance with the system; that Russia has declared her readiness to follow, when the United States shall have also joined the long list of nations who have established it in good earnest; that China, at once the eldest and the youngest of the family of nations, is on the eve of establishing the same standards; and that, even in conservative England, its use has been authorized by statutory enactment; so that the elegant and harmonious system of meters and grams now stands in the same legal category with avoirdupois, troy and apothecaries weight, with beer-measure and wine-measure, cords, acres, stones, quarters of various sorts, and all the other arbitrary and incongruous denominations, which nothing but hereditary acquisition could save from the verdict of utter absurdity; divided too, as they are, into parts of 3, 4, $5\frac{1}{2}$, 6, 8, 12, 14, 16, $31\frac{1}{2}$, or whatever else they may be, certainly not decimal.

Two very extended investigations, in which Mr. Bache bore an important part, ought not to be omitted from mention here. The first is the well-known and elaborate Report upon Water Power, by a committee of the Franklin Institute, a document prepared by Mr. Bache, although he took no part in the published portion of the experiments. The other is the Report made in 1836, on the Explosions of Steam Boilers, which cost him some years of hard work, and is signed by him alone in behalf of the committee of the Franklin Institute. It is elaborate and learned, and rendered essential service in promoting judicious legislation. The causes of explosions are considered under five general divisions, comprising all the causes at that time recognized. Yet it is a most instructive consideration for the student that we are now, after the lapse of thirty years, aware that one of the most serious sources of danger arises from a cause at that time unknown: namely, the sudden evolution of steam in consequence of temporary diminution of pres-

sure, and, perhaps, the mechanical agitation, produced by lifting the safety-valve, — the pressure of this steam, when disengaged, surpassing that which had previously sufficed to confine it in the liquid form. Happily, this source of danger also has now been obviated, by means of a principle closely analogous to that, which at this time, formed the subject of another of Mr. Bache's investigations, and regarding which his experiments led to an unfavorable report: namely, the principle of circulation in the water of a boiler. The celebrated Jacob Perkins, seizing, with the quick perception of genius, upon this principle, which had long been employed in the bleacheries of continental Europe, undertook, by introducing into the boiler an inner lining, open at the bottom, to confine the generation of steam to the annular space between the boiler-wall and this false lining, thus causing an upward current within this space, maintained by the water descending through the central core. The theory seemed good, but Bache's experiments showed that, far from greatly promoting the generation of steam, such small influence as was exerted by the inner cylinder, was in the opposite direction.

Now that we have the additional knowledge of thirty years on the subject, we easily perceive the reason. The water foamed in the annular space, not because it did, but because it did not, circulate freely. Had the water in the inner vessel been unable to receive any heat which had not traversed the outer one, and had the ratio of the sectional area of the inner vessel to that of the annular space been twelve or fifteen times greater than it was, a rapid circulation would have been established; foaming would have disappeared; the rapidity of formation of steam would have been increased three fold; and the water would have remained in such a condition that no diminution of incumbent pressure could occasion a sudden evolution of steam.

In the same year he made a thorough survey of the track and the effects of a severe tornado which had visited the vicinity of the city of New Brunswick, and obtained quantitative, as well as qualitative, determinations of its effects. The results here, as, likewise, those of similar subsequent surveys of tornadoes near Newark and near Philadelphia, tended to confirm the then

new and unpopular theory of Mr. Espy, of an inward motion near the surface of the earth.

But I am dwelling far too long upon the manifold labors of this preliminary period of Bache's scientific career. To present an analysis of his labors during those seven years, would be an agreeable task; but far more than a proper portion of this discourse has already been demanded by the variety of their scope. Ingenuity, mental activity, interest in all branches of the physical science of the day, and a zealous industry that shunned no toil, characterize this early period of his career, as emphatically as that of his maturer life. Six chemical papers lie before me; among them are an analysis of anthracite coals, made jointly with Professor H. D. Rogers; experiments on the corrosion of metals by salt water; on the action of different alkalies in conferring hydraulic properties upon lime, and on a new method in alkalimetry. Here, too, are nine others, yet unmentioned, upon subjects in thermics and meteorology; among them, three historical notes, 1st, on the date of Dr. Franklin's discovery that our north-east storms begin at the south-west, fixing this date satisfactorily in 1743; 2d, on the received hypothesis to explain the greater quantity of rain which falls at the surface of the ground than above it; and 3d, on the discovery of the non-conducting power of ice; the origin of both these latter being conclusively traced to his great ancestor. There is a charming little paper describing experimental illustrations of various phenomena in thermics. There are methods of recording the force and direction of the wind, subsequently introduced with benefit into the Coast Survey. There are meteorological observations, and observations of meteors, simultaneously with Mr. Espy, for determining their height, and with Professors Henry and Alexander, for determining longitude, these last being the first successful ones made for this purpose; and there is one of the most noted of all his memoirs, the investigation of the Influence of Color upon the Absorption and Radiation of non-luminous Heat.

The basis of these experiments was the principle, that for each substance there is a thickness beyond which radiation from it is constant, so that their radiating powers are rightly compared, not by equalizing either their thickness or their weight,

but by determining, for each substance, what the thickness in question is. Obtaining then a variety of pigments, of the same color differing chemically, and of kindred chemical composition differing in color, he undertook to determine their different powers of absorption and radiation; as, also, the modification of these powers, which changes of color, occasioned by chemical means, would produce. The principle in question was established, but no connection between color and radiation was detected.

I pass from this interesting period of Bache's life with an allusion to one more of his works, at that period eminently characteristic of the man, his polemical discussion with Olmsted regarding the periodical recurrence of meteors. Mr. Bache maintained that there was no recurrence in 1834; Professor Olmsted, on the other hand, maintained the reverse. Professor Bache instituted special inquiries at the military posts, where of course sentinels were on duty, along all the frontiers of the United States; also among the night-police of various cities, and at the Universities; and he found but one exception to the statement that no unusual number of meteors was seen. Of this controversy Bache wrote, in 1846:

"There is something yet to be found out on this subject, which may reconcile our opinions. Neither I, nor any of those watching with me, or for me, have seen an unusual number of meteors on the night of the 12th of November, in any year since the great night at Philadelphia, and we have taken great pains to be sure. Yet, I cannot doubt the testimony as given for some other places. . . . I had a complimentary letter from the Professor in regard to my manner of conducting the controversy, which I valued more highly than if I had gained the victory."

That "something yet to be found out" we now know, thanks to our colleague, Professor Newton, and to the brilliant celestial confirmation of the correctness of his computations on the night of November 13–14, 1866 and 1867. It affords the anticipated reconciliation of the two opinions, while the history of that controversy illustrates the firmness, mildness, charity and courtesy of our lost friend and leader.

Thus earnestly, variedly and successfully prosecuting his physical investigations, surrounded by a genial circle of friends, whose companionship he always loved to recall, enjoying the

affection of his pupils in the University, filling an important position in the management of the Philosophical Society and of the Franklin Institute, winning for himself an honored name on both sides the Atlantic, dwelling with his kindred, their stay and staff, — his busy life went on, till suddenly a new path of usefulness opened before him, and led to an interruption of the whole tenor of his thoughts and ways.

Stephen Girard had died in 1832, leaving an immense sum of money for the endowment of a college for orphans. In 1833, Professor Bache had been elected one of the Trustees of the college, and on his thirtieth birthday, July 19, 1836, he was, by the unanimous vote of the other Trustees, appointed President of the Institution. On accepting this new position, so full of promise, he received instructions to visit Europe, in order to examine similar establishments there, and thus to procure the means of opening the college under the most favorable circumstances. Accordingly, resigning his post in the University of Pennsylvania, he prepared for an immediate departure, and sailed for Europe September 30, 1836.

During two years happily and profitably passed in visiting the principal countries of Europe, he formed many close friendships among the leading investigators of physical science, while actively prosecuting the especial objects of his mission; and moreover found opportunities for a determination of the magnetic dip and intensity at twenty-one European points, with the same apparatus and by the same methods which he had employed in America, thus rendering it possible to combine the results of both investigations, without danger of introducing extraneous errors. These objects once accomplished, he returned in October, 1838, in the hope and expectation of insuring an early opening of the college. During the winter of 1838–9, he prepared his "Report on Education in Europe," a large octavo book of 666 pages. Of the contents of this elaborate volume, I will not enter into any detailed analysis before the Association. By the universal consent of those best competent to judge, it enjoys the reputation of a master-piece. The fruits of an examination of about 280 schools, comprising examples of all the principal educational institutions below the grade of Universities in Great Britain, France, Switzer-

land, Holland, Italy, and the several German States, are here systematically presented; though the work claims only to be an abstract of the more prominent parts of the mass of documentary matter brought home by Mr. Bache, and arranged under his direction, so that, to use his own words, it might "always throw the light of experiment upon doubtful points in the working of our system of organization. In many cases the documents descriptive of the schools give the actual results of suggestions contained in the works on education."

The history of the delays in the opening of the Girard College, of the vast sums and almost interminable time expended on the construction of the building, and of the various other difficulties, which seemed full of unhappy auguries, needs no repetition here. No effort was spared by Professor Bache to accelerate the opening of the institution. We have seen that he hastened home immediately on the completion of his labors in Europe, notwithstanding the cordial recommendation of the Trustees, that he should remain. At the beginning of his report he says:

"It is almost needless to say, that I am now not only ready, but anxious to render available as soon as possible, in the organization of the Girard College, the knowledge which has thus been acquired. A due execution of the instructions of the scholastic committee required not merely an examination of orphan houses and elementary schools, but of the various modes of education and grades of instruction. . . . I must be allowed to say, that in the course of attempting its execution, I have spared no personal exertion; and though I may regret it was not in abler hands, my conscience acquits me of having wasted any parts of the time and means so liberally placed at my disposal by my fellow-citizens."

A year passed by; the imposing structure, in which the orphans were to receive their education, remained unfinished; Professor Bache's salary continued; but there was no work for him to do. His mind was filled with the ideas and experiences on educational matters, which had accumulated during three years of continuous application to inquiries in this direction. Being therefore alike unwilling, by resignation of his office, to abandon the bright prospects which his enthusiasm had portrayed for the future of the college, or to receive a salary for which he was rendering no manifest equivalent, he conceived

the idea of offering his services gratuitously to the city of Philadelphia, for the purpose of reorganizing its High School, then lamentably deficient in many important respects. His offer was accepted, and he received and assumed the position of Principal of the High School, which he retained for more than a year, effecting during that period a complete reformation of the school, which soon assumed position among the best in the land. Finding then that the college was still not in a condition to promise any speedy commencement of its activity, he insisted on resigning his salary, although against the remonstrances of the Trustees. He retained, however, the nominal office of President, and held himself ready to assume its active duties, whenever opportunity should offer. Meanwhile he received from the civic authorities the joint position of Principal of the High School and Superintendent of Public Schools; together with a salary which, though but little more than half that which he resigned, was a liberal one for those days. This position he retained for nearly two years, until in July, 1842, three years and a half after his return from Europe, he was reappointed to his old position in the University, and left the city-schools. His reoccupation of the Professorship was, however, of short duration, for in November, 1843, he received the appointment of Superintendent of the Coast-Survey, and here, at the age of thirty-seven years, began the great and crowning work of his life.

During the five years since his return from Europe, though his time and energies were greatly drawn upon by the exigencies of the educational duties, his scientific labors had been by no means intermitted. He had published his observations of the magnetic dip and intensity at twenty-one stations in Europe. He had organized a magnetic observatory at the Girard College, and raised the means for the prosecution of observations during a series of years, which demonstrated for the first time that the small changes of magnetic declination in Europe and America are not similar. He had invented an ingenious instrument for determining the dew-point, which is even now probably the best one available for that large class of cases, where the observations must be made by men not specially trained to scientific investigation. A series of com-

parative observations, with this instrument and the wet-bulb hygrometer, for about two years, is among the records of the Girard College Observatory. Long afterwards, Bache found that Belli of Milan had anticipated him in the general principle upon which the instrument depends. "The form of my instrument," said Bache, "is quite different from his, and I think it has advantages enough to entitle me to keep the name, but alas, principle was the soul, and I do not care much to dispute for the dead body."

The principle consists in cooling one end of a conductor below the dew-point, while the other is at the temperature of the air. The intermediate parts then assume different temperatures, and some one section will have the precise temperature of the dew-point. The conductor is quicksilver, contained in a highly polished metallic tube, on which the marginal line of deposition of dew becomes sharply marked. A thermometer, plunged in the mercury at this point, indicates, of course, the degree of temperature sought. The details of contrivance in this instrument are admirably managed; and, although doubtless the neat device of Regnault for attaining the same result, by the evaporation of ether from a thimble, furnishes a more accurate method in the hands of a philosopher, it may be doubted whether, in those of a mechanical observer, it would be found preferable.

During the same period he had introduced a modification of Osler's anemometer, avoiding the friction of the apparatus necessary for guiding the spring, as also the exposure of the spring to the weather and to great fluctuations of temperature. He had made a series of numerous experiments with Fourier's thermoscope of contact, in order to determine the conducting powers of powders and tissues, hoping thus to remove the obstacles which had prevented the farther prosecution of the subject of his first published paper, that on the inflammation of phosphorus. But finding these results unsatisfactory, he had invented a new thermoscope of contact better adapted to the purpose, and capable, by a slight modification, of being applied to a determination of the conducting powers of liquids.

And, besides these, he had carried on his investigations upon heat to a very considerable extent, and although the results

were not, in his opinion, sufficiently definite and complete to justify their publication, still his expressions of hope that he might yet resume and complete these researches were ever earnest.

I cannot refrain from making known the reason of their discontinuance.

One room on the sunny side of his house was appropriated to these experiments; the various thermoscopes and all the subsidiary apparatus were arranged there, and the apartment was held sacred to scientific investigation. One evening, while he was attending a session of the Philosophical Society, an alarm of fire broke out in the neighborhood. His mother, then a member of his family, heard the alarm, and hastily entered the room without a lamp, to look from the front window. A crash reminded her, too late, of the inconsiderateness of her movements. The apparatus was entirely destroyed, and the first words which greeted her son on his return told him what he had lost. He made no reply, but went to the room and silently surveyed it. The destruction was complete, and the hard labors of nearly a year were rendered fruitless. An eye-witness has described it to me. He stood white with emotion for a few moments; then, turning away, only trusted himself to say that he would return soon, and hurried out of the house. Half an hour in the open air restored him to himself; returning, he consoled his mother, and made light of the occurrence; nor did he ever afterwards explain the reason why his observations on heat were discontinued.

It was in November, 1843, that Mr. Bache was appointed to the Superintendence of the Coast-Survey, his appointment to the Office of Weights and Measures following, a month later. The volume of testimonials and recommendations, upon the strength of which this appointment was made, has been shown me; and their number and character has made a deep impression. I cannot believe that such a weight of recommendation was ever brought at any time in support of a candidate for office, on purely intellectual grounds. I can think of no man in the country, eminent in physical science or holding a prominent scientific position, whose name was not signed to some one of that voluminous mass of memorials, asking the appoint-

ment of Professor Bache. All the scientific societies and colleges, together with several of the learned associations of Europe, gave their influence and added their indorsement to the request. How such a unanimous declaration on the part of experts could have failed of success, it were difficult to conceive; assuredly it was tenfold more honorable than any mere appointment. But to all these was added a yet more effective influence, growing out of the personal and political relations which by good fortune were brought to bear, and which it was impossible to resist. The President, Mr. Tyler, issued the commission, in spite of the avowed and vigorous opposition of the Secretary of the Treasury, Mr. John C. Spencer, under whose immediate direction the Coast-Survey belonged.

So far as the earnest and unanimous support of the lovers of science in the country was concerned, (science had then few, if any, real votaries other than those who were incidentally enabled to prosecute their studies in the intervals of other professional labor,) Mr. Bache entered upon his new duties with confidence. But he found his position one in which such moral support could afford but little aid. Internal disorganization, insubordination and dissension embarrassed him on the one hand; and the distrust and unconcealed animosity of the Secretary shackled him on the other. These were circumstances to evoke and make manifest the true greatness of the man.

Mr. Hassler, his predecessor, was a man of high attainments and ability, whose scientific management of the work, which he had himself initiated, had won universal approbation. He had emigrated to this country from Switzerland at the very beginning of the century, and had brought with him ideas of scientific accuracy and thoroughness, which the public mind in America was not yet sufficiently enlightened to appreciate, or even to understand. He gave to the Survey the chief energies of his life, and, undeterred by its suspension for nearly fifteen years, resumed its prosecution, when permitted anew, with the same zeal which had marked its inception. In Mr. Bache's words, "For his successful struggle against great difficulties, his adopted country will, no doubt, honor his memory, as the

pioneer in a useful national undertaking." On the other hand, he was a man of great eccentricity of manner, and not endowed with administrative ability. Science was at a low ebb among Americans when he came to our shores, and but few received the benefit of the scientific knowledge which he brought with him. Excepting Nicollet, himself a foreigner, and Dr. Patterson of Philadelphia, Hassler appears to have little acquaintance, and still less personal intercourse, with learned men in the United States. The scientific development of the country seems to have gone on unperceived by him; and, to quote the words of one who knew him, "he died in the belief that the nation as a whole, was, in 1843, where he had found it in 1801, so far as its science was concerned." Comparatively few native Americans obtained employment on the Survey under him, and one of his surveying party has informed me that he himself was the only man of that party who spoke English habitually. His scientific affiliations were exclusively transAtlantic, and while he seems to have entertained a sort of general affection for his adopted country, he apparently looked upon Americans as necessarily tyros in scientific matters, and deemed the refinements and elegancies of the higher Geodesy matters entirely beyond their comprehension. When on one occasion he had applied for an increase of salary, the Secretary of the Treasury, upon whom he was urging his claim, is said to have replied, "Why, Mr. Hassler, that is as much as I receive myself;" to which with charming frankness he replied, in strong Swiss accent, "What if it is! Any President can create a Secretary of the Treasury; but only the Almighty can make a Superintendent of the Coast-Survey."

"At the time of Hassler's death," I quote the language of a distinguished officer of that period, "the condition of the Coast Survey was anomalous and Ishmaelitish. Every man's hand was against his neighbor. Hon. John C. Spencer, the Secretary of the Treasury, was the real head of the Survey; and the principal assistants reported directly to him, and not to Mr. Hassler, who was thus reduced to the position of nominal Superintendent, but the real Chief only of the primary triangulation party."

Mr. Spencer was, as I have said, strongly opposed to Mr.

Bache's appointment. He favored the claims of the senior assistant. The two assistants, next in order of appointment advocated the same, desiring to see the principle of succession by seniority established. Other assistants urged yet other men, but none favored Mr. Bache. After his appointment, four of the eight yielded their coöperation, as did a fifth after a time, but the others were as ingenious as they were active, in devices for establishing and maintaining a system of petty persecution. Never was magnanimity more grandly exhibited than in Mr. Bache's course, while making himself Superintendent in fact as well as in name; but on this there is no need to dwell. Illustrations of his greatness of spirit are wanting at no period of his career.

Perhaps I may best illustrate the conciliatory power of Mr. Bache, and the magnanimity of Mr. Spencer, by reading to you a letter, written by the latter at the time of his resignation, being only five months after Mr. Bache had taken charge of the Survey in opposition to his wishes. It is addressed to Professor Bache, and forms a fitting pendant to the other letter, already laid before you.

TREASURY DEPARTMENT, May 1st, 1844.

Sir: — I am unwilling to leave this Department without communicating to you the great pleasure I have derived from the intercourse which has subsisted between us since your appointment as Superintendent of the Coast Survey; and my conviction of the great service you have already rendered the country in the arrangements made for carrying on that work. The system, order and regularity to which you have brought the complicated and difficult operations of that great work, afford the strongest assurance that it will now proceed with vigor and despatch, as well as with economy. My thorough knowledge of all your difficulties, plans and improvements, derived from the intimate communications that have been maintained between us, justify me in saying, that in my opinion the work could not be entrusted to more capable and judicious hands than yours. I shall look forward with great anxiety to the accomplishment of those great results which I am confidently anticipating in the successful prosecution of your very laborious and highly responsible undertaking.

With great respect and esteem,

Your friend and servant,

Prof. A. D. BACHE,
Sup't Coast Survey.

J. C. SPENCER.

In these five short months the moral and intellectual power of Bache had not only triumphed over the obstacles which the Secretary mentions, but over the numberless misrepresentations to which he had at first lent an ear; and finally over the Secretary himself, whose manliness forbade him to retire to private life without first leaving a public record to remedy any previous injustice. He had regarded and described Bache as a "mere college professor," without practical administrative ability, or any special qualification for the Coast-Survey. But he saw and acknowledged the error, and remained his fast friend until death.

Six months thus passed in establishing authority, and in learning the precise condition of the work which he had undertaken to prosecute, and regarding which the continued ill will of the three senior assistants and the chaotic condition of its affairs, had at first thwarted his endeavors.

But at last, freed from the influences of internal disorder and dissension,—having gained the confidence of the Treasury Department, having established discipline with the three insubordinate assistants, without any manifestation of unkindness on his own part, and having secured the respect and cordial regard of the other officers of the Survey,—Professor Bache was able to apply his energies with effect to the development and prosecution of the great undertaking before him.

The first step was to enlarge the scope of the work, avoid sectional jealousies, and accelerate its execution, by dividing the coast into sections, in each of which a base-line should be measured and the triangulation extended in opposite directions from this base to the confines of the section, where the work of the adjacent one would meet it; each thus testing the other. The advantages thus gained in soothing prejudices, already serious in those States which the connected primary triangulation of his predecessor had not yet reached, was greater than I can describe, and conduced in no small measure to the public favor and support, which his tact and discretion, even more than his scientific power, soon won for the Coast-Survey. Within the first year, the operations of the Survey were carried on in nine States of the Union; within the second, in twelve; within the third, in fourteen, notwithstanding the withdrawal of all the army officers, on account of the Mexican

war; and within the fourth year in seventeen,—the Atlantic and Gulf coast having been divided into nine sections, a division still retained.

The first season was in a great degree devoted to the trial of instruments and methods. The thirty-inch theodolite was, and is to this day, a truly serviceable instrument, but the astronomical apparatus belonged to a by-gone era. To Lieutenant T. J. Lee, and to Mr. Boutelle, both of them gentlemen of experience in practical observation, was assigned the duty of testing the instruments available for latitude-determinations, the chief of which was a Borda's repeating Circle. After a summer of faithful and repeated trials they reported that their best results for latitude had been obtained with the vertical circle of a six-inch Gambey theodolite, which they had borrowed. There were three transit-instruments, two of them five feet long, and the third and best of the three, only two feet. All proved unequal to the demands of geodetic astronomy in 1844, and were soon replaced by instruments of more modern construction. Observations of the dip and variation of the needle, and of the intensity of terrestrial magnetism, were introduced as part of the regular routine. So too were observations of the tides. The employment of solar observations for determining azimuths was exchanged for observations of the pole-star at both elongations. The form of geodetic signals invented by Mr. Borden, and used by him in the trigonometrical survey of Massachusetts, was substituted for that previously used; and is still regarded, by common consent, as the most accurate and convenient form ever devised.

As rapidly as means allowed, the services of American scientists throughout the land were enlisted in aid of the Survey, and the whole intellectual resources of the country thus made tributary to its usefulness and success. Thus Walker, Peirce, Bailey, Agassiz, Barnard, Kendall, Mitchell, Bond, Alexander, and many others were called on to assist in the advancement of the undertaking; and this large and wise policy prevailed during the whole period of his superintendence. Various other institutions took the name "national," but there was only one really national scientific institution for the first twenty years of his administration, and that was the United States Coast-Survey.

As the work gradually expanded under his guidance, many of the ablest officers of the Army and Navy were brought into the Coast-Survey service. They found an opportunity for the use and development of their powers which otherwise might long have remained wanting, and gladly served under a civilian who manifested such a knowledge of men, and such a capacity for using them. It is surprising to see how many of our ablest military and naval officers found employment, and attained distinction, in the Coast-Survey. Of the army, I need only mention the present Chief of the Engineer-Corps, General Humphreys, the worthy follower of Totten, Generals Stevens, Foster, Prince, Cullum, Cram, Hunt, — so too Johnston and Hill, whose intellectual powers were then enlisted in their country's service. Of the navy, among others, —Vice Admiral Porter, the two Rodgerses, Davis, Gilliss, Sands, Craven, Ammen and Luce. During our late war, a large majority of the most useful commanding officers of the navy had served upon the Coast-Survey, and they did not hesitate to assert that their experience there had been of the highest service to them in the naval duties of the war.

In the second year of Bache's administration the base-apparatus was perfected by him, the Zenith Telescope first employed in the Coast-Survey for the determination of latitude, and the exploration of the Gulf-stream commenced. In the third, the magnetic telegraph was first introduced as a regular geodetic method for the determination of longitude, and a special party organized under Mr. Walker for the prosecution of longitude-operations. In the fourth year, a chronometic expedition was organized for the better determination of the transAtlantic longitude, and the method of star-signals adopted for telegraphic measurements, — a method "destined," to use Walker's own words to this Association, "sooner or later to perfect the geography of the globe." The system of magnetic and tidal observations had then attained an extended development; and arrangements were already in progress for the measurement of two arcs of the meridian, and one of a parallel of latitude.

I will not undertake any detailed narration of the successive stages in the development of the Survey under Professor Bache; but a few words may be deemed not amiss regarding

some of the more marked steps in its progress. The apparatus for the measurement of base-lines, devised by Professor Bache in 1845, and constructed by Würdemann, whose services had even at that early day been secured for the Coast-Survey, and to whose exquisite skill and ingenuity many of the details are due, attained a degree of excellence before unknown. It can be safely asserted that with this apparatus, under Bache's skilful manipulation, the practical sources of error became less than the theoretical, or, in other words, that a line could be measured with such precision that the uncertainty arising from all errors of every kind, incurred in the measurement, was less than the uncertainty in the length of the standard of measurement. This wondrous accuracy was attained by the introduction of two new principles, both due to Professor Bache.

Owing to differences of specific heat and conducting power, different metals subjected to the same circumstances; do not change their temperatures with equal rapidity. Consequently an apparatus constructed for perfect compensation by the joint employment of brass and iron, on the principle of the gridiron pendulum, may not be correctly compensated, so as to remain of unvarying length during a change of temperature, which is in fact the very condition which naturally exists at the time of use. By numerous experiments Bache succeeded in so arranging the cross-sections of the bars, that while the extent of their surfaces remained the same, their masses should be inversely as their specific heats, allowance being made for their conducting powers. The same varnish being applied to the surface of each, in order to confer equal absorbent capacity, the compound bar must then retain the same length, not merely at all temperatures, but during all changes of temperature.

The other principle which he introduced consists in the substitution of actual for optical contact, thus dispensing with the use of microscopes, a practical gain of great value in the field. The contact-level of Bessel finds here an appropriate application; the agate plane, carried indirectly by the compensation lever which connects the brass and iron at their free ends, abuts against an upright lever on the other bar, which transmits the pressure to the contact-level.

A description of this exquisite apparatus was given to this

Association at its Washington meeting by our lamented colleague, the late Major Hunt of the United States Engineers. At Bodie's Island in North Carolina, Professor Bache measured a base-line six and three-fourths miles long, in ten working days, with a total probable error of less than one tenth of an inch. On one day at this time, 1692 meters, or one and a sixteenth miles, were measured in eight and a half hours. In measuring the base on Epping Plains in Maine, 8716 meters long, the probable error committed was less than sixteen millimeters; and the probable error of any distance in the primary triangulation of the New England States is to its total length, as 1 to 288000.

The determination of latitudes with the Zenith Telescope by Talcott's method was first tested in 1845, and proved so far superior to any other known means of determination possible in the field, that it was adopted by Professor Bache for the Coast-Survey operations. I need not tell you of the excellences and precision of this method, for it is now more than twenty years since the attention of astronomers was first called to it, while the annual Reports of the Coast-Survey, and numerous communications to scientific periodicals in this country, have furnished continual illustration of its preëminent merit. And in a recent number of the Proceedings of one of the leading scientific societies of Europe, published in this very year, 1868, attention is called to the Coast-Survey method as a very excellent one, and well deserving of a trial! Here, too, as with the base-apparatus, a degree of accuracy is attainable in observation, surpassing that afforded by the fundamental data; so that not the errors of instrument or observer, but those of the star-declinations, limit the correctness of our results. To Bache we owe the recognition and adoption of this transcendent method, and to him also those refinements of process and improvements of apparatus, by which alone its accuracy is rendered possible.

To the telegraphic determination of longitudes, and the development of the method of star-signals, I have already alluded. The latter was soon found applicable, with almost equal advantage, to the regular observation of transits in fixed observatories, and all the apparatus devised for the one purpose answered with equal aptitude for the other.

The simple and easy process of making telegraphic comparisons of clocks, whose respective errors are determined by local observation, was early discarded in spite of its tempting facility, since the apparent accordance of results thus obtained soon showed itself illusive. Bache's rule in the Coast-Survey was that all the scientific work should be executed in the most thorough and accurate manner which the resources of science and art would permit. He never shunned a tenfold labor, if it was to be repaid by double precision, accepting the great principle which prescribes a higher rate of effort as we climb to higher degrees of refinement. Nor did another great law which the history of science has taught from the beginning, and is teaching now, fail of its continual application and illustration; just as it will not fail hereafter, unless all inferences from experience are futile. This law ordains that the conscientious investigation of truth for its own sake shall be rewarded by some unforeseen practical benefit. The struggle to attain, at whatever effort it may cost, all possible accuracy throughout those investigations whose value is dependent on their precision, finds unexpected recompense in new clues to phenomena before unknown, and in the disclosure of new laws. Thus it was that the method of star-signals led to the method of telegraphic registration, now universal in observatories.

This important advance in practical astronomy received its full development in the Coast-Survey. There, long years ago, its methods were brought to the same degree of refinement and completeness of detail, which they have but recently attained in Germany. The precautions requisite in observing, the study of personal equations both in noting the transits and in reading the records, the modes by which the clock can best be made to graduate the time-scale, the various forms of chronograph for maintaining that time-scale, — all sprang from the Coast-Survey, and received their full development either from the regular offices of the Survey, or from others acting temporarily as assistants. Among the earliest results of this method as applied to the measure of longitudes were the discovery that the time required for the transmission of signals by electric telegraph was appreciable, and therefore measurable, and the determination of

their velocity. These investigations and results were of course not all of them due to Bache directly or alone, but none the less were they due to him. Not merely to the general expansion which he gave to the operations under his direction; not merely to the large policy, according to which he secured astronomers for astronomical, physicists for physical, and mathematicians for mathematical, research. These would indeed have been ample grounds on which to claim for him a large share of the honor due for valuable discoveries and successful applications. But in fact his personal relation to the results was far closer. He knew, understood and guided, even when one or more other minds were active between him and the results. Accomplished himself in practical observation, skilful in experiment, thoroughly acquainted with the progress of all the larger investigations prosecuted by others under his direction,—he was no administrative officer in that too frequent employment of the term, which dispenses with the understanding of work directed to be done by others, and actually makes the words "administrative" and "executive" to denote opposite qualities. Day by day, step by step, in the successive detection of principles, elaboration of methods, discovery of facts, he was in constant intercourse with the investigator,—stimulating his zeal, encouraging his hope, suggesting new ideas or infusing needful caution. Yet with unfailing magnanimity he never claimed in such cases any personal honor for success, nor did he disown any personal responsibility for failure. May I be allowed to repeat a sentence which I addressed to this Association fifteen long years ago, when we mourned together over the loss of Walker, and you had called on me to recount his honorable deeds? In speaking of the method of star-signals, I then said:

"Mr. Walker has informed me that this suggestion was due to the Superintendent of the Survey, but its practical application seems to have been a result in the elaboration of which the two bore an equal part. At least I may be permitted to state the still more honorable fact, that in the very many conversations which it has been my privilege to hold with each of the two gentlemen separately upon this interesting question, their descriptions varied but in one salient point, namely, that each ascribed the chief merit to the other."

Thus by the use of the Zenith Telescope, combined with the determination of longitudes from the adopted meridian by the

exchange of star-signals, the geographical position of the primary astronomical stations of the Survey could claim, ten or fifteen years ago, to be determined with more accuracy than that of any European observatory.

The temptation is strong to recount the similar advances made through Bache's administration of the Coast-Survey, in almost every department of physical science. Not only Geodesy and Astronomy were thus made gainers by new methods and implements of research, but other sciences were similarly promoted and their advancement stimulated.

Stations for tidal observation were established all along the Atlantic, Gulf and Pacific coasts. Self-registering tide-gauges (the invention of the ingenious Saxton, whose invaluable services Bache early secured, and retained to the last), were brought into extensive use. Our knowledge of tidal phenomena and laws assumed new proportions, and by unwearying persistence in questioning, the secret of many a mystery in their complicated action was extorted. The character of the ocean currents along our coasts was determined, and their causes elicited. All along the shores of the Atlantic, Pacific and Gulf of Mexico, beyond the lines of soundings, the deep-sea lead, and the deep-sea thermometer were busily plied by the exploring vessels of the Survey, while the immediate coast was fringed with a net-work of soundings, — the deep-sea lead, thermometer and sounding lines all being at the same time essentially improved. Twice was Agassiz sent to study the coral reefs of Florida, to discover the method of their formation and the laws which promote and restrict their growth. The most accomplished students of the infusoria were kept supplied with specimens from the dredge and sounding line for their microscopes. The magnetic instruments were improved, and the magnetic constants determined for every important point possible, within the reach of the Survey.

The exploration of the Gulf-stream, commenced in 1844, was vigorously prosecuted, its temperature at the several depths determined, and its structure and laws for the first time detected. The cold wall of water between the Gulf-stream and the shore, as also the division of the stream proper into alternate bands of warmer and cooler water, were discovered, meas-

ured and mapped out for the benefit of navigators and the use of scientists. So too were a series of nearly parallel ranges of hills at the bottom of the stream, the most westerly being 1500 feet high, and the whole forming a series of corrugations corresponding with the bands of warm and cold water. The facts that the general direction of the stream is governed by the configuration of the bottom and that the temperature varies from year to year, thus standing in an important relation to the meteorological phenomena of the coast, were also detected. These discoveries were, in a large degree, made by Mr. Bache individually, upon a study of the observations, although no small share in them justly belongs to Professor Trowbridge. In the year 1860, fourteen sections of the stream had been surveyed, 300 positions upon them occupied, and 3600 observations of temperature made.*

But I must not continue in this strain. That Bache touched no question of science which he did not adorn with new discoveries and new means of attaining yet farther ones, — that the range of the Survey was made to cover almost the whole range of physical science, from the structure of the microscopic dwellers in the bed of the ocean, up to the improvement of

*During Professor Bache's Superintendence of the Coast-Survey, the positions of 9816 geodetic stations were trigonometrically determined.

4989 triangulation-stations were occupied.
267 magnetic-stations were occupied.
68 base-lines were measured, being 150 statute miles in total length.
102 longitudes were astronomically determined.
151 latitudes " " "
82 azimuths " " "
12850 square miles of area were topographically surveyed.
38850 " " " " " hydrographically "
7222449 soundings were taken.
7500 specimens of bottom were obtained and preserved.
1030 tidal stations were occupied.
133 shoals and reefs were discovered and determined.
41 important channels were discovered and their changes determined.
1020 current stations were occupied.
970 topographical snap-sheets were constructed.
877 hydrographical " " "
270222 sheets of charts were printed.

In addition to these the positions of many hundreds of isolated rocks, ledges and shoals were for the first time accurately determined.

The party directed by Professor Bache in person occupied, during the same period, 49 primary triangulation-stations, measured 6 base-lines, of which the aggregate length was 33 statute miles, and determined astronomically 5 longitudes, 29 latitudes, 31 azimuths.

lunar tables and the determination of positions of fundamental stars,—you all well know.

I have said that to him the scientific progress of the nation is indebted, more than to any other man who has trod her soil. Nor was this bold statement made in forgetfulness or ignorance of the great debt we owe to many illustrious men. Nor do I fear that any of you who know his services will think it overstrained or ill-considered. I call you to witness that it is true; that not his great ancestor who outvied Prometheus, not the statesmen who have guided the legislation of the republic, not all the educators, who have shaped the policy of its colleges and schools, not all the great masters in physics or mathematics, zoölogy or geology, have so effectively, widely or intensely stimulated the advancement of science in America, as Bache did through the agency of the Coast-Survey. What was the branch of physical science, which was not called upon to minister to the Survey, or which failed to receive an impulse from it in return? Had the chief object of this work been the promotion of scientific research, it could not have been more effectively aimed at, or attained.

Addressing a scientific body on the scientific career of our departed leader, it is only from this especial point of view that I have considered his administration. But that would be a very one-sided presentation of the facts, and one eminently unjust to his memory, which should leave on a single mind the impression that the scientific researches or influences, of which I have spoken, were attained at the sacrifice, or disregard in the slightest degree, of those important practical purposes for which the Coast-Survey was established and supported. So too would it be unpardonable to omit, from the recital of his services and achievements, the work he did for commerce, for the national defence, and for the development of national resources. All this he accomplished the more thoroughly and the more economically, in that he called to his aid the resources of the highest science. Although embarrassed by difficulties peculiar to our own country and offset by few corresponding advantages, his survey of the Coast of the United States may challenge comparison, as regards its completeness and thoroughness, with any geodetic or hydrographic work

ever executed. The ocean currents have been explored with untold gain to our seamen, the variation of the needle, and its rate of change, determined with unsurpassed precision along the three seaboards of our country, the tidal laws so well determined that the tide-tables published by the Survey for many years have been found conformable with observation to a degree previously unattained in any part of the world, the heights of mountains and the depths of oceans measured and mapped out,—and all this accomplished at a cost inferior, almost beyond comparison, to that of similar surveys in other countries. As has been well said by Professor Trowbridge, the annual cost of the Survey, at the time of its most extended activity under Mr. Bache, was but little more than the cost of a first-class steamship. It never reached an annual cost approaching the price of some of the floating palaces which ply upon Long Island Sound, or up the Hudson. Nor was there probably a single year of the twenty-three years of Bache's superintendence, when the discovery of reefs, shoals, currents, channels or rocks, would not have been cheaply purchased by the nation, at an outlay of all the survey ever cost. So much it may not be amiss to say upon this purely practical point, since, though of course needless for you, it might not be so for others to whose eyes these words may come.

But his benignant influence was not alone exerted through the agency of the Coast-Survey, with which his name is, and forever will be, associated. Can any of us forget his relation to this Association, of which he was one of the founders? No man surpassed him in efforts for its success. Never absent, never without some tangible proof of interest and good wishes,—his counsel, more than that of any one man, was sought on all questions of policy, and his opinion received with unsurpassed respect. Over three of the fifteen sessions of the Association held during his life, he presided, and hither he brought the annual contributions of his abundant discovery.

So was it also with the National Academy, the complement and coadjutor of this Association. There too he was a founder, the most active member, and its President. And but for the bitter dispensation which cut him off amid his usefulness and honor, his well-known voice would have sounded in your

ears, calling on both institutions to stand firm by one another, mutually supporting, mutually dependent, and capable, by joint action and reciprocal confidence, of accomplishing fourfold what either could do alone.

So too was it with the Smithsonian Institution. From the beginning he was a Regent, and to his active support and earnest endeavor, more than to that of any other, we owe it that this Institution, under its present honored head, has been able to adopt and to maintain a policy, which shall make it what its founder intended: "an institution for the increase, and the diffusion of knowledge among men." It is safe to say that, but for Bache, Professor Henry would not have assumed the Secretaryship, nor have been willing to retain it; and but for Bache, his wise policy would in all probability have failed of full adoption.

No scientific undertaking, indeed, failed to receive from Mr. Bache hearty sympathy, personal assistance, and whenever circumstances warranted, official support. Gilliss's Expedition to Chile, Kane's and Hayes's Polar expeditions,—all of which, like many others on a minor scale, he served with his counsel, his influence, his official assistance and his purse,—illustrate his anxiety to aid the extension of human knowledge.

But it was not merely by his ardent love of science, and disinterested devotion to her welfare that he accomplished so much. His fertility of device, unconquerable assiduity, large policy, generous impulses, patriotic devotion, might well have coexisted without yielding such fruits in the development of the Coast-Survey, or such a mighty power for good in the promotion of science throughout the United States. More than these was needed; far more than these he possessed. It would be safe to say that the greatest of all his mental gifts or attainments were his marvelous knowledge of human nature and his unrivaled skill in using it. He had studied men, as he once expressed it to me, as he would study physical phenomena. To a faculty of persuading the most obstinate, of soothing the most irritable, of encouraging the most disheartened; to a power of stimulating the indolent, controlling the impulsive, winning over opponents by the charm of his manner, and confirming friends by the truthfulness and sincerity of his nature,

—he added that rare endowment, which imbued others unconsciously with his own zeal. His was what might be called a magnetic nature, for his companionship evoked latent aspirations, and pointed to noble aims. It was to his personal, more even than to his scientific, qualities, that the Coast-Survey owed the recognition of its importance by Congress and the people, and the annual provision made for its maintenance. He knew the secret of obtaining work from his subordinates, by doing more than they did. His desire to accomplish much himself led him during half the year into the field, where he in person performed the most difficult geodetic operations; thus insuring the accuracy of the portion accomplished by himself, and maintaining such an intimate acquaintance with the practical details as enabled him to understand the real needs of those engaged in similar operations elsewhere. Annually he made tours of inspection through all the sections accessible to him. He took a personal share in the details of all the explorations; and no assistant, permanent or temporary, felt, in entering on a new field, that his duties or powers were clear before him, till they had been thoroughly discussed with the Superintendent in person.

The qualities in which he manifested a high order of genius were especially those by which he governed men. Had his tastes been military or political, instead of scientific, none the less would he have been a Chief. It may safely be said that by no act of his life did he ever curtail any man's means of usefulness, or fail, whenever it was in his power, to render available whatever abilities might be disclosed. Justice and even-handed firmness controlled his action. No man was ever readier to acknowledge and atone for a wrong done by him, in thought or deed. Cautious in plan, bold in action, generous without impetuosity, as courteous and considerate of his subordinates as though they had been his superiors, ever as open to conviction as to argument, such was his noble character. With these traits was united a feminine tenderness of heart, and an intensely sympathetic nature. To him all came for comfort in personal sorrow, for sympathy in bereavement, for help in calamity. And his purse, like his heart, stood open to his friends, and to the needy.

In a critical analysis of his character, the traits which I have just mentioned would occupy the most prominent place, but with them the mention of one other quality would be imperative. I allude to his keen appreciation of humor, his love of pleasantry and jest, and his social geniality. These alleviated the cares of severe administrative duty, and the anxieties inseparable from his official position,—peculiarly great in our own form of government, where the needful appropriations are made by legislative bodies continually varying, and where the personal hostility of a single individual may be made the occasion for denunciation of a national work. Without his social qualities, and his power of banishing at will the oppression of grave cares, his precious life would scarcely have been spared one-half so long, as it was in fact vouchsafed us. This love of humor, so essential in a well balanced mind, was his in no stinted degree, and often was he the center of a group of delighted friends, whose enjoyment of his fun was scarcely exceeded by their reverence for his intellectual and moral worth.

His administration of the Coast-Survey was by no means an easy one in its political relations. For many years there was scarcely a session of Congress, without some vehement attack upon the Survey in each House, made for the purpose of defeating the appropriations. The causes of these were various, and many of them will occur to you without enumeration. Hostilities growing out of his original appointment and incapable of being allayed, jealousies on the part of other institutions professedly established for kindred purposes, resentments on the part of persons subjected to discipline, furnished fuel for the flame, in the form of ready assistance to whatever threatened the welfare of the Survey, come from what quarter it might. At one period, the representatives from inland districts, impelled by narrow local jealousy, opposed the expenditure of public money for purposes which they supposed not so useful to their own States as to others. At another time certain naval officers disseminated, to a considerable extent, the impression that, because it was a Coast which was the subject of Survey, the work should be placed in charge of nautical men. At still another date, similar claims were urged in behalf of the

army. But the minds of the people, and of their legislators became enlightened, so that for some time before the recent war, the facts were recognized, that the services rendered were to no particular State so much as to the nation, and that the helpful aid of army and of navy were alike requisite, as well as that of a corps of civilians trained exclusively to the work.

One of the most violent of these organized attacks was made about the year 1849, and doubtless resulted in permanent good to the Survey, from the multitude and earnestness of the manifestations which it called forth from all parts of the United States, and from Europe. The learned Societies, the Insurance offices, Chambers of Commerce and Boards of Trade, throughout the land, hastened to send their testimony to the services which it was rendering, and their earnest protests against any interference. Men of the highest eminence throughout Europe joined in the appeal. In August, 1849, Schumacher wrote him:

"In an epoch like this, where everywhere associations are formed for material interests, it is high time that we also unite our forces, to protect the higher and purer scientific interests. . . . You will see by the inclosed letters of our common friends, Mr. Arago and Baron Humboldt, how anxious they are to know if the great work you have undertaken will remain in the hands to which the whole scientific world would have intrusted it. Let us hope that the fear they entertain is only founded upon vague rumors. Your country must be proud to call you her own, and will repay you in gratitude what you do for her scientific glory."

A month previous Arago had written to their common friend:

"There is a rumor here that Mr. Bache is threatened with losing the place he is filling in so distinguished a manner. I beg of you to give me information about it, so that we can join with all the most distinguished scientists of Europe to prevent so great a misfortune. The officers of the American navy are proverbial for their gallantry; they know perfectly well every part of the nautical art; still, I shall do them no wrong by stating that Mr. Bache stands higher than they by a hundred cubits in matters of Geodesy, and Physics of the Globe. And I will prove by numerous examples how very useful it is even for the truth of the results, that a man should be superior to the task intrusted to him."

So also Humboldt:

"You know better than I do in how high an estimation the Direc-

tor of the Survey of the Coast stands, not only among us, but among all the most illustrious men, who in France and England are interested in the study of Geography and Nautical Astronomy. . . . In a region of the globe where the direction of oceanic currents, the difference of temperature produced by these currents and by the upheaval of the bottom, and the direction of the magnetic curves offer so important phenomena to navigators,—such a great work could not be better placed than in the hands of Dr. Bache. The government of the United States has acquired a new right to our gratitude by protecting nobly this that has already fixed the attention of the Hydrographers and Astronomers of Europe. I should be glad to think that in a country, where I am honored with so much regard, my feeble testimony might contribute to enliven the interest which is due to the excellent labors of Dr. Bache."

The President of the Royal Geographical Society of London, in his Annual Address to the Society in 1852, commented with expressions of strong admiration upon the practical management of the Survey, and characterized it as "one of the most perfect exemplifications of applied science of modern times." And six years later, Murchison, then President of the same Society, in his address presenting to him the great gold medal, used this language:

"Whether we regard the science, skill and zeal of the operators, the perfection of their instruments, the able manner in which the Superintendent has enlisted all modern improvements into his service, the care taken to have the observations accurately registered, his modest and unpretending demeanor, or the noble liberality of the Government, tempered with prudent economy, all unprejudiced persons must agree that the trigonometrical Survey of the United States of America stands without a superior."

Such expressions as these, uttered from all quarters at home and abroad whenever the work was menaced, speedily removed in every instance, all occasion for alarm to its friends.

The last serious attack was in 1858, when Bache's firm and unyielding defence of the scientific interests at stake in the well-known contest at the Dudley Observatory, was the occasion for the most virulent of all the onslaughts ever made upon him. At first it was supposed that by the inauguration of a regular system of attack upon the Survey, Bache would be frightened from his position at the Observatory. But where either moral principles or the interests of science were involved

he knew no fear, and what was commenced as a means of alarm, was continued only in the spirit of revenge. The daily press was filled with attacks upon the Survey, its policy, its value and its Superintendent, some of them violent and some insidious. Pamphlets were prepared and sent to members of Congress at their homes, and to all prominent public men in Washington. Relations were opened with former opponents of the Survey, and with all who could be found, supposed to be disaffected towards it in any way. It is a source of peculiar regret that obvious circumstances preclude me from entering into many particulars and illustrations here, which others might have laid before you; and which would place in strong relief the magnanimity, the force, and the lofty chivalry of spirit in our lost leader. He stood like a rock, upon which the storm beat in vain.

> "O iron nerve, to true occasion true!
> O fallen, at length, that tower of strength
> Which stood four-square to all the winds that blew!"

It will forever be among my most precious memories that in that time of trial, it was my privilege to receive his approval from the beginning. The very last, the passive abandonment of the moral struggle, when physical force became involved, was the only step which failed of his full indorsement. This was to me the greatest pain of all; but happily dispersed, when upon farther knowledge of the circumstances, his opinion was changed, and his priceless approval extended to the whole of my course in that bitter contest.

A year later, at the Springfield meeting of this Association, a Report on the History and Progress of the American Coast-Survey, was presented by a committee of twenty men of science not connected with the Survey, and who had been appointed for the purpose at a previous meeting. Fortunately the attacks of the preceding year had failed of their effect, in consequence of the manifestly personal motives which inspired them, and of their evident connection with the Observatory at Albany. This able report, commenced by Judge Kane of Philadelphia, and after his death prepared by our honored late President, Dr. Barnard, then at the head of the University of Mississippi, presents a thorough analysis of the great work ac-

complished, and the strong language in its praise, with which the report concludes, received the unanimous indorsement of the Committee.

But this inadequate sketch of Bache's services would be yet more incomplete, were the record of his scientific achievements, during the last twenty years of his life, confined to the work officially done through the Coast-Survey, which he had made so essential to science in America.

His own investigations and discoveries during this period have not been enumerated, and though from the nature of the case they were mostly derived from data collected by the operations of the institution to which he devoted his energies, none the less were they the fruits of his own intellectual labor. I have endeavored to prepare a catalogue of his own memoirs,— a large proportion of which were presented to this Association, which he fondly cherished, and upon the sessions of which he was an unfailing attendant.

Most of these memoirs are upon subjects connected with the new methods which he introduced into the Survey, the measurement of bases, or the phenomena and laws of the tides, of the Gulf-stream, and of terrestrial magnetism. These phenomena and laws he unraveled and developed, to an extent which warrants us in regarding him as the principal source of our knowledge of their more complicated action. To our Providence meeting, in 1855, he communicated a remarkable paper, on the progress of an earthquake-wave in December previous, which was detected on our Pacific coast by means of the self-registering tide-gauges. This wave he traced from Japan,— where it had occasioned serious damage to the Russian frigate "Diana," in the port of Simoda, and where the highest of five successive waves was about thirty feet,—to Peel's Island, one of the Bonin group, where the first wave rose to an altitude of fifteen feet above the high-water level,—and thence to the shores of Orégon and California, where the disturbance was recorded at Astoria, San Francisco and San Diego; at which last-named station eight waves were traced upon the tide-gauge, the largest being six inches in height. From these observations he deduced the speed of six miles a minute as the rate of the wave's motion, and the mean depth of the Pacific as

about 2300 fathoms on the San Francisco path, and about 2100 fathoms on the San Diego path.

Meanwhile he had conducted, in connection with General Totten and Admiral Davis, special researches of a highly important character, nominally independent of his position as Superintendent of the Coast-Survey. He thus served as Commissioner upon the harbors of New York, Boston, Charleston, Portland, and the Cape Fear River; and the reports contain investigations concerning the formation of obstructions in rivers and harbors, and the laws controlling the improvement and deterioration of channels, which have largely contributed to our knowledge of these laws.

At the Albany meeting of this Association, in 1856, he communicated among other valuable papers, a very important memoir from himself and Mr. Hilgard jointly, upon the general distribution of Terrestrial Magnetism in the United States. At Montreal, he described the chronometric longitude expedition, then recently carried out by him in person; the base-line which he had just measured upon Epping Plains in Maine; and the principal characteristics of the winds of the Western Coast of the United States. At Baltimore he presented an investigation of the personal equation in determining latitudes by Talcott's method; and a memoir on the tidal currents of New York Bay. At Springfield he gave a discussion of results deduced from the declinometer-observations made at Girard College, from fifteen to twenty years before; and a third memoir upon the Gulf-stream, showing the distribution of temperature in the waters of the Florida channel and straits. At Newport he added two papers containing theoretical results from the magnetic observations at Girard College, one upon the solar-diurnal variation and the other upon the influence of the moon upon the needle.

When the outbreak of the rebellion gave a new direction to the energies of all the Bureaus of the government, Bache was of course found at his post, equal to the occasion. When a secret commission of three was organized to devise measures and provide plans for the blockade of ports, or the capture of important points on the sea-board of the insurrectionary territory, the military and naval skill of officers high in command

in their respective services was reinforced by the knowledge and sagacity of Bache, whose personal ability gave added value to the charts of the Survey. More than one General-in-chief looked to him for daily counsel during those days of doubt and anxiety. He carried on experiments for improving the system of signals, he arranged and carried out a multitude of military surveys, and contributed from the Coast-Survey office a large proportion of all the campaign maps furnished to commanding officers. As Vice President of the Sanitary Commission from the first, his leisure from official duties was given to patriotic and humane efforts in behalf of our soldiers. And finally, in 1863, when his native city was threatened with invasion, he offered his personal services for arranging and superintending a system of fortifications. To his intense labor here, under many difficulties and amid numerous other cares, is to be attributed the fatal malady which interrupted his work, and took him from us in the very height of his usefulness, his power and his renown. In the language of the Faculty of his own University,

"He is justly to be regarded as a martyr to the cause of good government and the principles of human liberty, his death being directly caused by the overtasking of his faculties, in his active and never ceasing endeavors to sustain the authorities of his country against the rebellion, and to promote the efficiency and comfort of those who were fighting in our behalf."

In the spring of 1864 came the blow. It came too in the form which he had himself dreaded; as it had come to Walker before him, as it came to Faraday with him, and as the activity of nervous and mental energy in our own country especially invites it to so many of our intellectual workers. The sword wore out the sheath; the restlessly toiling brain gave way, and refused longer to obey the untiring mind. The repose, then imperative, came too late. After a summer of quiet in his camp, where he nominally continued his personal share in the triangulation which connected the New England stations with Hassler's stations in New York, he sailed for Europe in the autumn, hoping for a benefit from change of scene. A multitude of friends assembled to join in the farewell. The steamer was under the command of Captain Anderson,

himself a scientist of no mean attainments, whose subsequent efficient services in connection with the oceanic telegraph, have deservedly given him a wide reputation, and whose sympathetic kindness alleviated the discomforts of the sea voyage. With touching earnestness, Mr. Bache insisted on carrying with him a set of instruments for determining magnetic constants at points to be visited during his journey. In England, France and Germany he revisited some of his scientific friends of old, but the excitement proved more than he could well bear, and this pleasure it subsequently became necessary for him to forego. It was a source of special gratification to him to meet Struve at Rome, where he was temporarily sojourning. After an absence of eighteen months in Europe he returned, and even then his friends could not utterly surrender their hopefulness. But the fatal blow had fallen, and time only rendered its effects more manifest. At Newport, Rhode Island, on the 17th of February, 1867, his spirit cast aside the broken instrument which it could no longer govern, and returned free and rejoicing, unto God who gave it.

I will not undertake to enumerate the manifestations of honor, which were paid the lifeless clay, as it was carried from Newport to its last resting place in Washington. In New York and Philadelphia civic honors awaited it, and it reposed in state while the tokens of respect and gratitude were paid. Amid emblems of mourning, flags waving down the masts and minute guns breaking the silence, it passed along the streets. A solemn and reverent company awaited it at the national capital, and guarded it till it should be no more seen on earth. And when the last rite was over, there was not one of that great assembly who did not feel that he had lost a treasured friend, and that his country's loss was beyond utterance.

Gentlemen, I have far exceeded the limits of time appropriate for an oral address. Yet I have failed to convey more than an outline of the work he did, the services he rendered, the man he was. But my imperfect words are not his eulogy. Far and wide over this great land are scattered memorials of the love and honor of his countrymen. Above the Pacific coast a lofty mountain bears his name, and towers over the shores to which so many of his thoughts were devoted, a fitting

monument to his memory. Amid the polar regions of eternal ice and snow, still his name records the services he rendered to science there; and far in the North-west, the clear expanse of a broad lake repeats the familiar sound.

But I will attempt to recall to you no more.

> "Peace! His triumphs will be sung
> By some yet unmoulded tongue
> Far off in summers that we shall not see. . . . .
> Ours the pain, be his the gain! . . . .
> Yet lifted high in heart and hope are we,
> When we remember that for one so true
> There must be other, nobler work to do.
>
> ---
>
> He is gone who seemed so great!
> Gone; but nothing can bereave him
> Of the force he made his own
> Being here; and we believe him
> Something far advanced in state,
> And that he wears a truer crown
> Than any wreath that man can weave him."

While greatness, conjoined with goodness, is held in reverence by men; while the intellectual advancement of a nation is rewarded by the gratitude of her sons; while the history of American science is read or written;—yes, until winds and tides no longer rise and fall; until shore and sea no longer follow their varied course in beach and cliff, headland and bay; until the sailor no longer fears the sunken reef, the drifting current, or the treacherous rock; until the mystic forces of earth fail to exhibit their varying play, and the lamps of heaven no longer guide the wanderer,—shall reverence, honor and gratitude adorn the name of ALEXANDER DALLAS BACHE.

CORRIGENDUM.—On page 2, line 5 from below, for "only child," read "only surviving child;" since the son, Francis Folger, lived to be five years old.

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OF

ALEXANDER DALLAS BACHE.

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1834—Oct. On the Variation of the Magnetic Needle. *Amer. Journ. Sci.* xxvii, 385.

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1855—Dec. Report of Advisory Council of the New York Harbor Commission. *New York Assembly Doc.*, 1856, No. 8.

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